MicroPower Step Up Low-Voltage Booster Module

Enables Practical Energy Capture from Low Power Generators

Advanced Linear Devices, Inc.

INTRODUCTION

While the practice of energy harvesting has emerged from the laboratory to the marketplace over the last few years, many popular energy sources capable of generating waste energy have yet to emerge as a practical application due to their inadequate voltage and current (power) levels. Power sources such as thermoelectric generators, electro-magnetic coils and single photovoltaic cells can generate potential ambient energy for harvesting. In practice, however, it has been difficult to reliably capture the ambient or "waste" energy generated by these devices due to the very low voltage and power outputs of these sources. Typical devices, thermoelectric generators, electro-magnetic coils, single photovoltaic cells and infrared emitters output voltages in the low hundreds of milli-volts and power outputs from micro-watts to low milli-watts. And they are generally intermittent as well. This combination of low power and intermittent operation makes recycling the energy emitted by these devices challenging, to say the least.

Most current techniques that attempt to increase the output of these energy generators require substantial compromises in implementation. The most common and somewhat successful approach is the technique of stacking multiple gain devices in series. This approach tends to be expensive and bulky.

The more practical and economical solution to this problem is to employ a unique electronic interface capable of boosting the output power to a level compatible with existing energy harvesting capture electronics. The recent development of a MicroPower Low-Voltage Booster Module designed by Advanced Linear Devices, Inc. (ALD), especially for low energy capture has bridged this gap to fill a significant void in allowing the practical application of energy harvesting to develop at a much faster pace.

“Unlike the general electronics industry that is braced for a negative impact from today’s subprime market conditions, various energy harvesting technologies and related power management ICs are poised for rapid and profitable growth” claims Linnea Brush, Senior Research Analyst, Darnell Group. “A convergence of several factors including new government regulations and economic incentives is resulting in a favorable environment for wireless sensor systems incorporating power sources based on energy harvesting.”

What is Energy Harvesting?

Energy Harvesting is defined as the process of capture, accumulation, storage and conditioning of wasted energy from surrounding environmental sources such as light, temperature and motion, to name a few. What makes capturing the energy from such sources challenging is that most of them simply cannot supply adequate power for any kind of useful purpose directly. To harvest this minimal power requires them to be interfaced to efficient energy harvesting electronics capable of outputting intermittent four and six volt power bursts as required.

Since harvested energy is, by definition, low in power and unpredictable, most energy harvesting implementations are viable only for intermittent duty-cycle applications. Such applications must be able to allow sufficient time for the available energy to accumulate during the periods when the application does not require power; i.e., when the application's electronics are in power down or sleep mode.

The primary missions for effective energy harvesting remains the same – accumulating power generated by ambient sources – to enable freedom from charging batteries, the AC power cord, or from refueling chores using conventional power sources by accumulating power generated by ambient sources. This type of freedom is especially valued if the deployment environment favors the maintenance-free aspects of operation of energy harvesting due to high maintenance cost concerns.

Energy Harvesting Devices and Technology

Energy harvesting modules currently in production such as the ALD EH300 operate with an output voltage range between approximately four and six volts, and typically dissipate less than one micro-watt. These modules tout high retention times and demand better than 90% energy efficiency for applications as practical alternatives to battery power.

A key design element in the ALD EH300 is high energy capture capacity. The energy harvesting module must retain the captured energy and store it over extended time periods. To make the device useful, its output must be able to power complimentary metal-oxide semiconductor (CMOS) logic circuits such as those in microprocessors and wireless sensor. As well, the EH3300 is designed for an extended operating life. With no wearable parts, it is designed to outlast the life of the system it will be integrated with. It also is designed to have an unlimited number of charge and discharge cycles - ideal for super cap or battery charging applications.

ENERGY GENERATING SOURCES

Energy harvesting technology is well established in three to five volt range. For example, piezoelectric elements are common energy harvesting generating sources used in supplying power to embedded and wireless systems. The EH300 requires a peak input voltage of at least four volts to start the energy capture process. This is no problem for piezoelectric generators, which can generate in excess of 100 volts depending on the area of the piezo membrane and the physical displacement. However the more subtle energy sources such as light, temperature and electro-magnetic cannot muster anywhere near that high of a voltage or current. Therefore, booster modules must be used with such sources to bring the output up to usable levels for the energy harvesting modules. The following sources all are ideal candidates for low-voltage frontend booster technology

- Electro-magnetic coils can create an output voltage for harvesting wasted energy when energized. The size of the magnet and the number of turns in the coil determine the voltage magnitude and output current one can expect to generate. However, to keep the physical size of the components under control for most applications, they typically generate less than 200 milli-volts.

- A single solar cell typically outputs 400 to 500 milli-volts, depending on lighting conditions. However, once it starts conducting, the optimal power-generating voltage for the single solar cell drops to almost half of that. This means that the electronics must be able to function with approximately 250 to 350 milli-volts to yield any useful power from a single solar cell.

- Thermoelectric energy generators consist of thermocouples connected together by hundreds of strands. It is possible to generate 150 to 250 milli-volts using TEGs. These devices can output up to a few hundred micro-amps in the form of high-current and low-voltage power. The very low voltages that TEGs generate need to be converted to a higher voltages and lower currents state in order to be useful for most electronic harvesting applications.

Piezoelectric elements, for example, are more established as energy harvesting generating sources in supplying power to embedded and wireless systems operating in the 3V to 5V range. They differ dramatically however from more subtle energy sources such as light, temperature and electro-magnetic in that comparatively high voltage can be generated from vibration and other physical displacements. The EH300 mentioned above requires a peak input voltage of at least 4V to start the energy capture process, which is no problem for piezoelectric generators, which can generate in excess of 100 volts depending on the area of the piezo membrane and the physical displacement.

Electro-magnetic coils are one form of energy generator that can create an output voltage for harvesting wasted energy when a magnet is passed by the coil. The size of the magnet and the number of turns in the coil determine the voltage magnitude and output current one can expect to generate. To keep the physical size of the components under control for most applications, these generators for example typically generate less than 200mV and consequently require a voltage booster module as the front-end to the ALD EH300 Energy Harvesting Module to boost the input voltage above 4 volts.

A single solar cell typically outputs 0.4 to 0.5V depending on lighting conditions. But once it starts conducting, the optimal power-generating voltage for the single solar cell can drop further. This means that the electronics must be able to function with approximately 0.25V to 0.35V to yield any useful power from a single solar cell. As with electromagnetic generators, single solar cell generators also require voltage boosters to be considered a viable energy harvesting power input source. By extension, any energy-generating device that has diode- output type of characteristic can benefit from an electronic circuit that accepts a single diode input energy and can boost that energy to become a 3V, 5V or even 10V power supply.

Thermoelectric energy generators consist of thermocouples that are connected together by hundreds of strands. It is possible to generate 150 to 250 mV using TEGs. These devices can output from micro-watts to milli-watts in the form of high current and low voltage power. The very low voltages that TEGs generate needs to be converted to a higher voltages and lower currents state in order to be useful for most electronic harvesting applications implying the need for an ultra low-voltage booster.

MICROPOWER LOW-VOLTAGE BOOSTER MODULE

Still in its infancy, energy harvesting continues to generate interest from a wide variety of practical applications and embedded systems – primarily as battery power replacements or backup. Those showing recent interest are applications that can effectively utilize energy generating sources which heretofore have not gone beyond the engineering lab due to very low source output energy. Since energy harvesting often requires a multidisciplinary approach in bringing systems to market, the low-voltage booster is viewed as the missing component to stimulate a major growth spurt in this nascent field.

Consistent with the input requirements for the EH300/EH301 Series Energy Harvesting Module, Advanced Linear Devices, Inc., has announced the EH4200 series Micropower Low-Voltage Booster Module designed to be used in concert with its EH300/EH301 Series. The family of booster modules includes a selection of models designed to match the output impedance characteristics of certain selected energy generating devices. The EH4200 module requires no external power source and derives its operating power directly from the energy generating source output with as little as 10 µW. This enables an onboard self-starting oscillator, which oscillates at a natural frequency depending on the source output impedance (50 to 950 ohms), source voltage level and resonating components onboard the EH4200. The oscillator waveform is coupled to a transformer resident on the module that in turn is output as an AC signal whose amplitude is proportional to the input power level.

Designed to boost the output of ultra low-voltage energy harvesting sources to within the capture range of the EH300 (4-6 volts), the EH4200 engineering team was challenged with developing a module with the capability to boost the input voltages from a low of 100mV to a minimum of 6.8 volts. This is a boost of 6.8/0.1 or 68X (whereas a 50mV input voltage boosted to 6.8V is a boost of 136X).

Advanced Linear Devices, Inc., approach to design the EH4200 booster modules required the implementation of special components that have very precise design specifications and thresholds. The use of precision gate trimming in the manufacture of these devices is one of the ways to achieve these specifications. The level of precision and the level of operating voltage and current are the new frontier in this field. Currently, ultra low-threshold voltage MOSFETS are used in energy harvesting circuits, but now even zero threshold MOSFETs should be considered for ultra low-voltage module design such as the EH4200 Booster Module.

Circuits that capture, accumulate and store energy from sub 0.5-volt sources require special design considerations. By examining the unique properties of ultra low-voltage sources, a new benchmark has been established for developing the circuitry that make these sources a practical power supply for a broad range of energy harvesting systems as well as other embedded applications.